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(54) System for tuning high-frequency dielectric resonators and resonators obtained in this manner.

(57) In a system for tuning a high-frequency dielectric resonator pair, resonating in the mode TEo1 in frequency bands e.g. from 400 MHz to 20 GHz, preferably from 900 to 4000 MHz, a male dielectric resonator DM, having an external diameter d penetrates into a female dielectric resonator DF, having an external diameter D and a height H; for getting the variations e.g. from 4 to 5% of the tuning frequency within the band from 925 to 970 MHz, the ratio d/D is included between 0.4 and 0.8 and the axial coupling or penetration p/H is included between 0.3 and 0.7 where h is the part of DM engaged axially in DF.

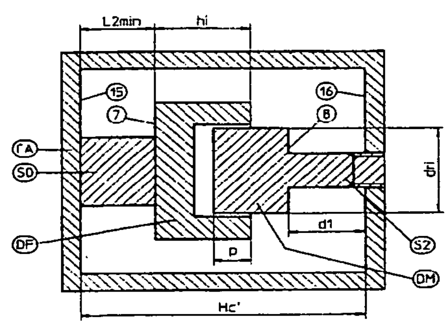

Fig. 4

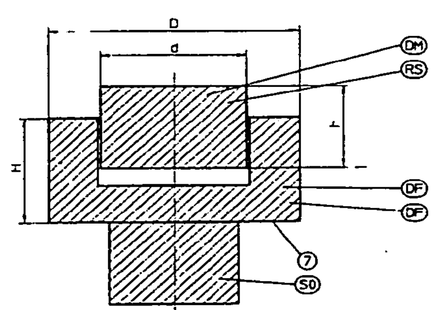

Fig. 4'

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SUMMARY OF THE INVENTION

The system according to the invention for tuning high-frequency dielectric resonators, resonating in the mode TEo1 in frequency fields e.g. from 400 MHz to 20 GHz, preferably from 900 to 4000 MHz, makes the coupling by means of the penetration of at least a male dielectric M having an external diameter "d" into a female resonator F having a diameter D and height H: in an embodiment, for getting the variations e.g. from 4 to 5% of the tuning frequency in the mode TEo1 within the band from 925 to 970 MHz, the ratio d/D is included between 0.4 and 0.8 and the axial coupling or penetration p/H is included between 0.3 and 0.7 where h is the part of M engaged axially in F.

DESCRIPTION

The present invention refers to a tuning system for high frequency dielectric resonators, in particular resonators working in the mode TEo1 from 400 MHz to 20,000 preferably from 925 to 970 MHz, in which system the tuning is obtained substantially by changing the penetration of a male resonator into a female resonator.

The invention includes also the resonators obtained by the considered system, including generally:

- a resonant cavity, preferably made of metal having a high thermal expansion coefficient;
- two interpenetrating dielectric bodies having a high dielectric constant and stability versus temperature; a support for each dielectric, and at least an adjustment member of the relative position between the two dielectrics.

Description of Prior Art

It is known the very fast development of the telecommunication technics; further it is known the tendency to transmit each time the maximum number of signals and then more and more wide frequency bands. In this connection the tuning plays an important function, in particular the tuning obtained by means of resonators including substantially resonant cavities. These last ones have originated the dielectric resonators obtained by the insertion into the cavity of at least a dielectric body generally having a cylindrical form and high values of dielectric constant and low values of the thermal expansion coefficient.

The high dielectric constant allows to miniaturize the resonators and therefore to work at frequencies included in the order of 1 GHz, for which frequencies the low air-loss resonators are too cumbersome. The great thermal stability is necessary for using the resonators in the very selective filters required by the great crowd of the frequency bands.

The resonators of the described type must be tuned in large frequency bands, in the inside of which the influence caused by the temperature onto the tuning members must be controlled. As these last members are anchored to an envelope that, owing to price reasons, cannot have a high stability, the problem arises of adjusting the tuning with the aid of means through which it is possible to exert a same influence on all frequencies of the tuning range notwithstanding the temperature variations. In fact only acting in this manner it is possible to make the thermal compensation in all frequencies of the tuning range.

Features, characteristics, geometries, advantages, etc. of the dielectric resonators are widely described in literature. E.g. at page 1 of the chapter "Design Consideration and Applications" of the catalogue of the Company Trans-Tech there are referred notices related to the short history of dielectric resonators and at page 2, Figure 5, the first and more used embodiment is described showing only one dielectric element (statinary and facing a metallic plate driven by a screw). The recent article "Tunable, Hybrid Mode dielectric Resonance..." by Chen and West, in APPLIED MICROWAVE Aug./Sept. 1989, pages 66 and foll. analyses different features of double dielectric resonators, schematized in Figure 1 at page 67, which is here aknowledged as Priot Art and is presented in the annexed Figure 1. Considering this figure, D1 and D2 indicate the two dielectrics having the free internal opposed faces 1 and 2 disposed at a reciprocal distance d = 2Lc, (where Lc is the distance of each face from the trace M of the symmetry plane); HD indicates the height (therefore the diameter in the case of a cylindrical dielectric) and Lb the thickness of each dielectric D1 and D2 respectively; S1 and S2 indicate the related supports with threaded screws, passing through the thickness of the metallic resonant cavity CA.

The Figure 1 represents D1 and D2 that are both adjustable by the screws S1 and S2 for modifying said distance d=2Lc between the opposed faces 1 and 2, but kept always SEPARATED AND PARALLEL with one another.

Decreasing the distance "d" (that is when "d" tends to zero) the minor frequencies decrease, substantially owing to the higher field concentration in the inside of the dielectrics.

This system allowed on one hand to solve the problem above all as regards the space, on the other hand it is affected by the unnegligible drawback of showing an unlinear law between the distance "d" of dielectrics D1 and D2 and the tuning frequency Fs within the wished band.

Owing to this unlinearity, at a parity of variation

of the distance "d", higher or weaker variations of Fs are produced according to the value of same Fs.

Similarly this unlinearity causes an influence, different at different frequencies, of the thermal expansion of the cavity CA to which the dielectrics D1 and D2 are anchored. Consequently the dielectrics thermal stability can be selected to compensate the cavity drift substantially at only one frequency.

The work by Kajfez and Lebaric "Numerical Analysis of the Tubular Dielectric Resonator with a Dielectric Tuning Rod" pages 1235-1238 dated 1989 IEEE MITT-S Digest, describes the case of a cavity with a dielectric resonator (hollow cylindrical in form) RU and a very little tuning rod TR mobile into RU.

The Figures 2 and 3 refer the schematic section of this experimental cavity, respectively the penetration diagram of rod/tuning frequency (as shown in Figures 1 and 3 of said work).

The diagram shows that it is not possible to have frequency variations in the band of f.i. from 5 to 10 GHz in the modes TEo1, TEo2, HEM11, HEM12, HEM21, HEM13, HEM22 and HEM14.

With a dielectric tubular resonator frequency variations even up to 14% are obtainable only in modes TMo1 and (in lower entity) in TMo2, however with interferences with HEM12, respectively HEM14. It can thus be seen that the experimental system including a sole tubular dielectric resonator and a dielectric threaded rod shows limits and complications.

Summary of the invention

The first scope of the invention is to provide a system that prevents the above mentioned drawbacks. Another scope is to provide a system that allows to get a "maximum maximorum" value in the main characteristics of a dielectric resonator, in particular a high linearity of the tuning frequency in function of the coupling between dielectric bodies, a compensation of the thermal expansion of the envelope (including screws and supports) substantially constant at all tuning frequencies and a greater miniaturization. These and other scopes are obtained by the system according to the invention, that is characterized in that variations from 4 to 5% of the tuning frequency generated with resonating cavities in the mode TEo1 within a band from 400 to 20,000 and preferably between 925 and 970 MHz are obtained by two dielectric resonators, the first being a female resonator with external diameter D and (useful axial) height H and the second being a male resonator with diameter "d" and penetration "p" into said axial extension "H" so that d/D is included between 0.4 and 0.8 and p/H is included between 0.3 and 0.7.

The devices for the embodiment of the considered system are characterized by two interpenetrating dielectric resonators, having critical reciprocal dimensions and coupling degree. The different features and advantages of the invention shall appear better from the description of the more immediate embodiments, represented in the accompanying drawings in which: Figure 4 is a schematical partial section view (similar to Figure 1) of a resonating cavity in the mode TEo1, particularly simple according to the invention, Figure 4' is a section view as Figure 4, but in enlaged scale for the sole resonators, Figures 5 and 6 are curves indicating the variation of the ratio ΔFs/Fs, i.e. is the percentage relative variation of the tuning frequency Fs, in function of the ratio p/H (percentage relative penetration) (Figure 5), respectively of the ratio d/D where d<D is the diameter of the little resonator.

As it can be seen from Figure 4, according to the invention the resonant cavity in the mode TEo1 includes two dielectric resonators, a first resonator Dm is now male and the second resonator Df is female. (In opposition to the Figure 1 in which the two resonators are not interpenetrated and always parallel with one another and in oppostion to Figure 2, in which the mode TEo1 is excluded).

Advantageously only one of the two dielectrics, e.g. DM, is mobile, that is it can be moved by the screw S2, the female resonator Df being fixed securely to a support So, as it can be seen better in Figure 4'. The first resonator Df (in axial schematic section) is U-shaped and is closed at one end or bottom 7, has an external diameter D and a height H from the bottom 7. The male body Dm has a diameter d<D, and a penetration "p" into Df, that expressed in relative terms becomes p/H.

According to the most important feature of the invention, it has been found (in opposition to the teachings of Figures 2 and 3) that, with a critical selection of ratios d/D and p/H, in the mode TEo1 it is not only surprisingly possible to obtain the wished variations of Fs in the band from 400 to 20,000 or better 925-970 MHz,but moreover that in a more unpredictable manner, it is possible to get substantially linear variations of Fs; with critical ratios of d/D from 0.4 to 0.8, preferably of 0.6, and p/H from 0.3 to 0.7 we have succeded to have linear variations of Fs, that corresponds to relative variations in percentage ΔFs/Fs from 4 to 5% within the band 925-970 MHz.

The diagram of Figure 5 shows the curves ΔFs/Fs in function of p/H (abscissas) for different values of the ratio d/D.

In a similar manner to what said with reference to Figure 3 of the known technics, it can be seen that for d/D = 0 and d/D = 1 (curve I) it is not noticed

any variation of $\Delta Fs/Fs$, therefore it is not possible to tune the cavity of Figures 4 and 4' at the frequencies included e.g. between 925 and 970 MHz.

A ratio d/D = 0 should correspond to the absence of the resonator DM or to the presence of a tuning rod TR, as shown in Figure 2, infinitely little with respect to the diameter of the sole resonator RU. On the other hand a ratio d/D= 1 substantially corresponds to the case in which the female resonator does not exists.

The curve II refers to the ratios d/D=0.2 or d/D=0,9; in this case the variations of $\Delta Fs/Fs$ are significant.

On the contrary and surprisingly, for d/D=0.4 or 0.8 (curve III) variations of $\Delta Fs/Fs$ already near to 4-5% are obtained, while for d/D =0.6 (curve IV) it is got a wide and decided variation of $\Delta Fs/Fs$ in a field slightly wider than 4-5%. Significantly the variation of $\Delta Fs/Fs$ is substantially linear for values of p/H included between 0.3 and 0.7 and of ratio d/D=0,6.

Figure 6 shows the variation of $\Delta Fs/Fs\%$ in function of d/D (for a fixed value of p/H equal to 0.5): it can be seen that the variation $\Delta Fs/Fs$ from 4 to 5% is accentuated and concentrated for d/D included between 0.4 and 0.8, with its maximum being at 0.6. The linearity of the portion of curve IV in Figure 5 (p/H included between 0.3 and 0.7 for d/D=0.6) is extremely advantageous.

In fact the device of Figure 1 allows an easy modification of Fs along the whole operative band changing the distance Lc between the two dielectric resonators. However the variation is unlinear on said whole band and depends on the absolute value of Fs.

This unlinearity is deleterious for the thermal compensation. A further advantageous feature of the invention can be evicted from what follows.

If in Figure 1 it is indicated by dmx= 2Lc the maximum compulsory distance in the conventional resonator for getting the maximum frequency of desirable tuning, then the length of said cavity must be $Hc=2L_2+2Lb+dmx$, where L_2 is the minimum distance the faces (3 respectively 4) of dielectrics must have with respect to the internal faces 5, respectively 5' of the metallic cavity CA for not causing dissipation losses in the metal; Lb being the axial length of cylinders D1 and D2.

On the contrary in the embodiment according to the invention the larger face 7 of DF must still respect the minimum distance L_2min from the face 15 of the cavity CA, the face with very reduced diameter "dri" of DM is now substantially uninfluent on the losses that can be caused by its proximity to the wall 16 of the cavity CA.

Therefore owing to the penetration "p" of DM into DF and the unnecessity of having, as in Figure 1, a maximum distance dmax= 2Lc between D1 and D2, the total length H'c of the resonator according to the invention is H'c=Hc-dmax as maximum.

All materials conventionally used for the metallic cavity and for the dielectric discs are useful for the use in the resonators according to the invention.

In particular the metallic part is made of aluminium and its alloys, the dielectric parts are made of materials available on the market and in particular the materials referred to e.g. in the catalogue NTK Microwave Dielectric Components page 2, that is purposely here mentioned also becouse at page 3 it refers images of dielectrics of the cylindrical type, drilled centrally along the whole axis (and with a crown having a diameter wider than the hole onlyon a little axial part). The hole has here the scope of preventing the deterioration of Q and improves the spurious responses.

All this has nothing in common with the spirit of the present invention.

For illustrative clarity's sake the invention was described with reference to the more simple embodiments represented in accompanying drawings.

It is however obvious that the invention is not limited to these embodiments but it can be submitted to variants, modifications, replacements and the like, that being within the reach of the mean skilled technician must be considered as naturally included within the spirit of the invention.

Claims

1. A system for tuning resonant cavities in mode TEo1 comprising high-frequency dielectrics, in particular resonators working in a wide frequency range e.g. from 400 to 20,000, preferably from 900 to 4000 MHz, in which system the tuning frequency is substantially obtained by changing the coupling between a dielectric resonator and a dielectric body, characterized in that for getting the maximum linearity between the wished tuning frequency and the dielectrics coupling, for compensating the thermal expansion of the metallic sheath in a manner substantially constant at all tuning frequencies and for further reducing the miniaturization, variations of 4 to 5% of the tuning frequency Fs in said band from 400 to 20,000 MHz in the resonant cavity with mode TEo1 are obtained by two dielectric bodies, both being resonant, the first resonator being male with diameter "d" and the second resonator being female with diameter D>d and with a depth H starting from the closed bottom, the male resonator showing a penetration h into H so that h/H is included between 0.3 and 0.7,

d/D being included between 0.4 and 0.8.

2. The system according to claim 1, characterized in that the resonator with major dimensions is kept stationary and the resonator with minor dimensions is slided in its inside.

3. A dielectric resonator system according to preceding claims, including a metallic cavity having a high thermal expansion coefficient, two dielectric bodies having a high dielectric constant in the inside of the cavity, tuning screws for causing the sliding of dielectric(s), characterized by a first female dielectric resonator having an external diameter D, and height H starting from the closed bottom, and a male resonator having a diameter "d" so that d/D is included between 0.4 and 0.8 and is engaged with the first resonator by a distance h so that h/H is included between 0.3 and 0,7.

4. The resonator system according to claim 3, in which the first female resonator is substantially a concave cylindrical element with a U-shape in cross-section, and is carried in an unamovable manner by a support internal to the cavity.

5. The resonator system according to claims 3 and 4, in which the second male resonator is cylindrical in form and has an external diameter "d" substantially equal to the internal diameter of the hollow wall of the female resonator, open at one end and closed at the bottom.

6. The resonator system according to claim 3 or 5, in which the ratio d/D is critically equal to 0.6.

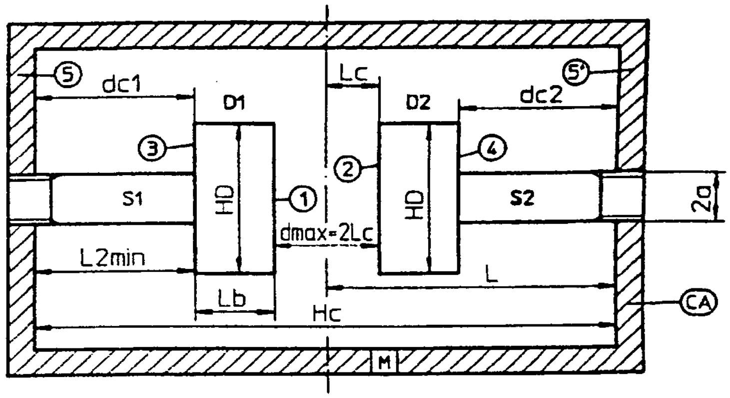

Fig. 1

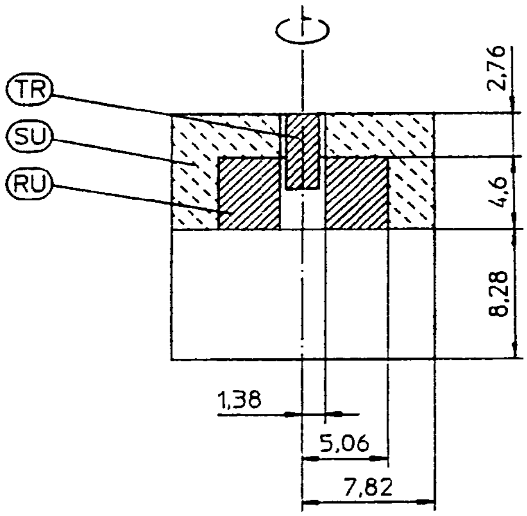

Fig. 2

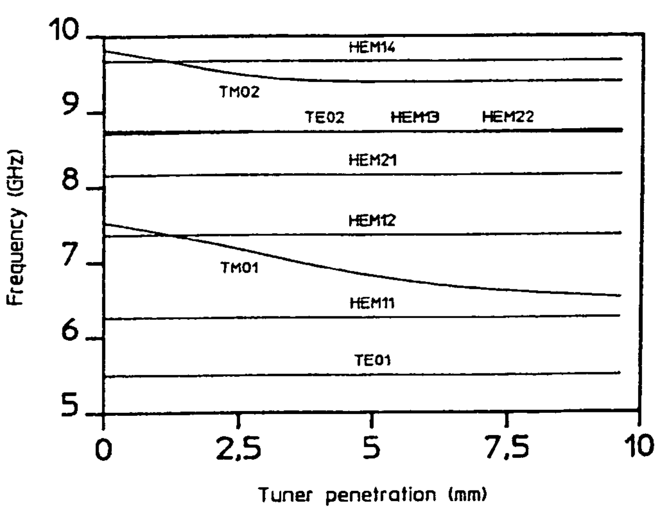

Fig. 3

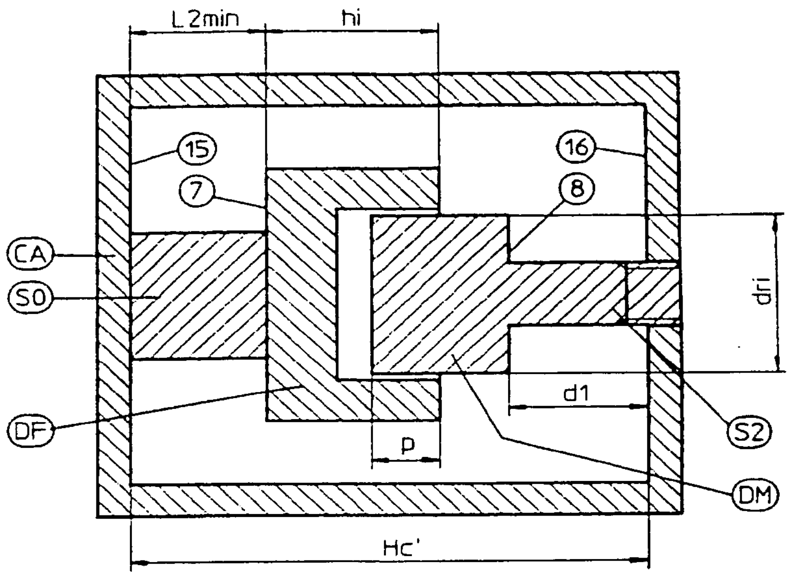

Fig. 4

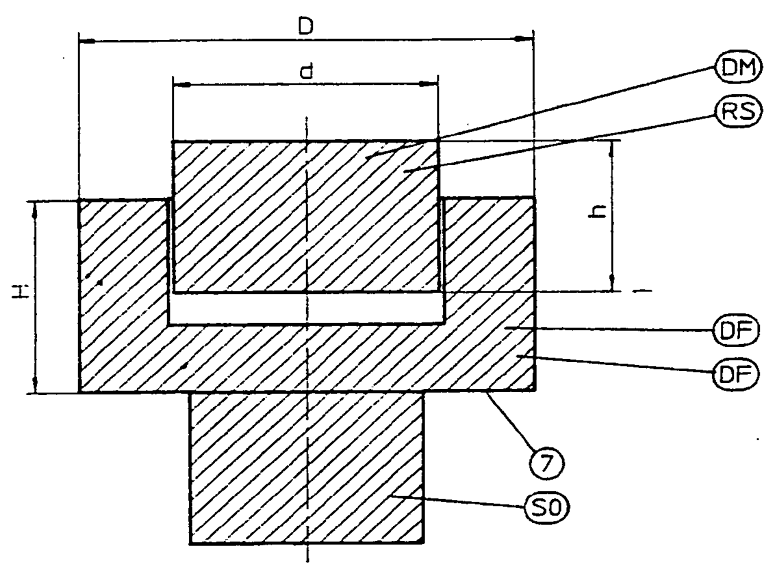

Fig. 4'

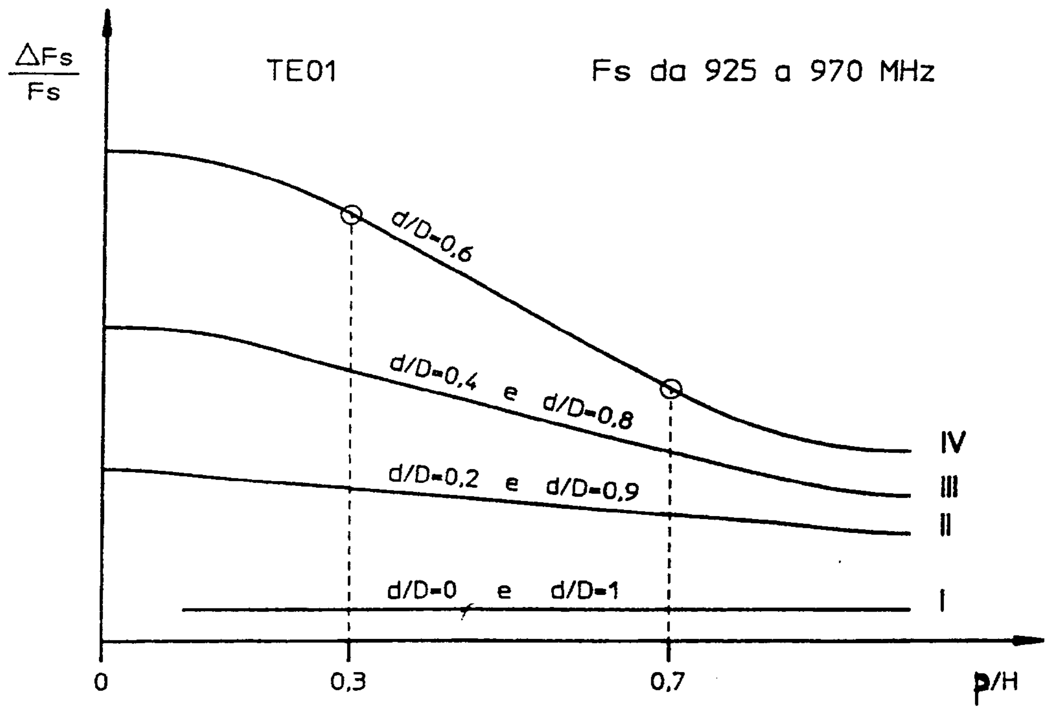
ΔFs / Fs
TE01
Fs da 925 a 970 MHz
d/D=0,6
d/D=0,4 e d/D=0,8
d/D=0,2 e d/D=0,9
d/D=0 e d/D=1
IV
III
II
I
0
0,3
0,7
ρ/H

Fig. 5

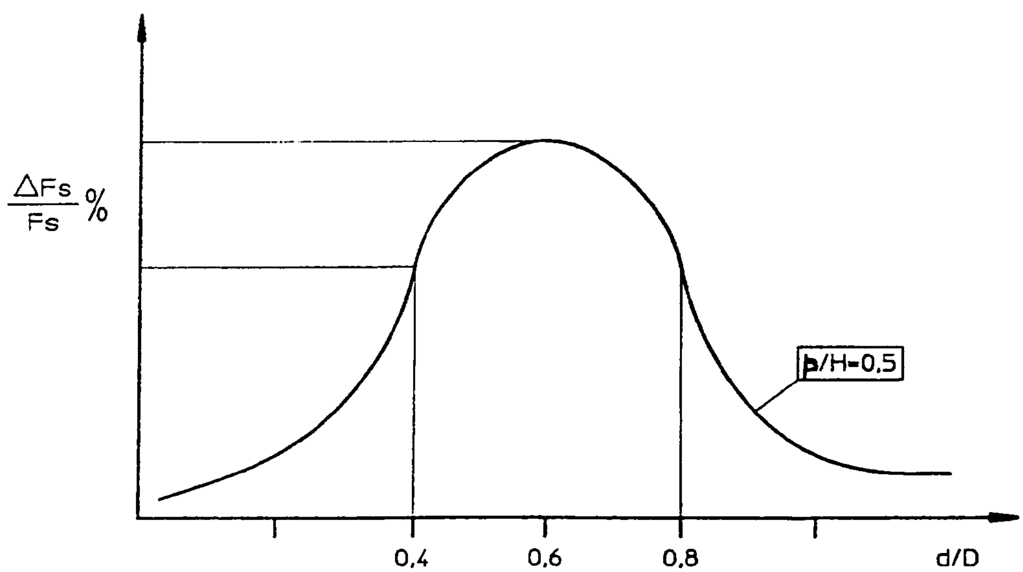
ΔFs / Fs %
ρ/H=0,5
0,4
0,6
0,8
d/D

Fig. 6

European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 91 12 1338

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
A	IEEE TRANSACTIONS ON MICROWAVE THEORY AND TECHNIQUES. vol. 17, no. 7, July 1969, NEW YORK US pages 354 - 359; M.A.GERDINE: 'A frequency-stabilized microwave band-rejection filter using high dielectric constant resonators' * page 354, right column, line 1 - line 10; figure 1 *	1,3	H01P7/10
A	FR-A-2 534 088 (MURATA MANUFACTURING CO LTD) * page 31, line 6 - line 34; figure 35 *	1-5	
A	PATENT ABSTRACTS OF JAPAN vol. 9, no. 248 (E-347)(1971) 4 October 1985 & JP-A-60 098 703 (MITSUBISHI DENKI K.K.) 1 June 1985 * abstract *	1,5	
A	FREQUENZ. vol. 39, no. 1/2, February 1985, BERLIN DE pages 45 - 49; U.CROMBACH ET AL.: 'Abstimmbare dielektrische Ringresonatoren' * page 45, left column, line 18 - line 26; figures 1,3,5 *	1,3,5	TECHNICAL FIELDS SEARCHED (Int. Cl.5) H01P H03B
A	SOVIET PATENTS ABSTRACTS Section EI, Week 8502, 20 February 1985 Derwent Publications Ltd., London, GB; Class W, AN 85-010541/02 & SU-A-1 092 621 (PISARENKO) 15 May 1984 * abstract *	1	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	17 MARCH 1992	DEN OTTER A.M.

CATEGORY OF CITED DOCUMENTS

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